NUCLEAR FUEL STRATEGY IN THE REPUBLIC OF BULGARIA

Guentcho Guentchev, Expert
Nuclear Fuel Cycle and Radioactive Waste Department
National Electricity Company Ltd, 5, Vesletz str., 1040 Sofia, Bulgaria

Krassimira Ivanova, inspector, Aneta Bakalova, inspector
Committee on the Use of Atomic Energy for Peaceful Purposes
69, Shipchenski prokhod Blvd., 1574 Sofia, Bulgaria

Tihomir Guentchev, radiochemist
1006 Cimarron, Park Way, ATLANTA, GEORGIA-30350, USA

ABSTRACT

This paper describes the current status of nuclear fuel cycle strategy in Bulgaria. The main part of the strategy consists of uranium mining and milling, fresh and spent nuclear fuel (SNF) of Kozloduy Nuclear Power Plant (NPP), Radioactive Waste from NPP and after nuclear application in medicine, industry, science, research, agriculture.

For last kind of wastes is constructed a near surface repository close to Sofia.

It is national policy to realize the Nuclear Spent Fuel Storage in Bulgaria. Some information for resources, production and demand of uranium mining and milling is shown in the paper.

INTRODUCTION

The Republic of Bulgaria is situated in the South-East part of Europe (Appendix 1). It is a small country with an area that is 111000 km^2. But it is a very interesting and very beautiful country as a nature and an environment at the same time.

Bulgaria has bordered on Romania to the North, on Greece and Turkey on the South, on Yugoslavia and Macedonia to the West and on Black Sea to the East (Appendix 2).

My country has got an ancient history. It was established in 681 after the Christ's Birth and it was accepted the Christian Faith in 888 after the Christ's Birth. These facts are written in the Vatican archieves of the Vatican laboratories in details.

Bulgarian nuclear politics includes three main parts as a follow:

- Uranium Exploration;
- Nuclear Fuel Management;
- Radioactive Waste Management.

URANIUM EXPLORATION

Historical Review

The dramatic change in uranium supply in the world over the last few years remains a key concern to the world's nuclear power industry and nuclear energy policy makers.

Uranium occurrences in Bulgaria were known at the Second World War including pitchblende in Bukhovo and autunite in Streltsha. Systematic uranium exploration started in 1945 with the co-operation of former Soviet Union geologists who discovered the first uranium deposits in Bukhovo area, near to Sofia sity. High grade ore war mined at Bukhovo as early as 1946. The ore was hand sorted and shipped to the former Soviet Union.

Systematic exploration started in the early fifties and covered the entire territory with Geiger-Muller airbone surveys. Despite the low sensitivity of this method, a number of uranium anomalies were detected. Some of them, including Eleshnitza, Smolian, Planinetz, Partisanska Poliana and Beli Iskar led to the discovery of significant deposits.

In addition, radiometric ground surveys were applied over 80 per cent of the national territory, as well as geochemical and geophysical exploration methods. Six hundred and forty km of exploration tunnels was driven, of which about 400 km were to investigate the syenite-black schist contacts. More than 18 million meters was drilled, about 86 per cent of them in sandstone uranium occurrences.

As a result of these efforts, total 35 uranium bearing districts were discovered between 1945 and 1990. Some of these, including Bukhovo, Eleshnitza and Momino contain several deposits [1].

Uranium resources from several important deposits

Table 1

Location	Total resources [tonnes U]
Bukhovo	5000 - 20 000
Eleshnitza	5000 - 20 000
Momino	5000 - 20 000

Uranium production

Uranium mining began in Bulgaria in 1946. The first mine was in the Bukhovo district, located about 20 km northeast of Sofia. In the mid-1950s several additional mines opened. Production was primarily by conventional underground mining. In situ leach (ISL) mining, using wells developed from the surface, was first tested in 1967 at the Orlov Dol (sandstone hosted) deposit in southestern Bulgaria Since 1981, 23 deposits were mined by conventional methods, 17 have been mined by ISL bore-hole systems and 11 have been mined using leaching in association with conventional mine development.

With the closure of at least 4 conventional mines in the late 1980s, by 1990 about 70 per cent of Bulgaria's uranium production were from ISL mining using surface boreholes. This production was from sandstone hosted deposits and in most cases, relied on acid leach technology. ISL minig was adopted to produce uranium that was uneconomic to mine using conventional underground methods.

In the recent past uranium production came from a number of mines and ISL facilities including Proboinitza, Kurrilo, Biala Voda, Eleshnitza, Simitli, Senokos, Smolian, Momino, Belosem, Pravoslaven, Haskovo, Navasen-Troian, Isgrev, Okop-Tenebo, and Sborishte.

Two hidrometalurgical uranium proccesing plants Bukhovo and Eleshnitza are stopped in operation. Through a few governmental acts whole uranium industry is liquidated. By a decree of 20 August 1992 the government of Bulgaria suspended all uranium production in the country.

Uranium requirements
At the end of 1998, as it was mentioned above Bulgaria had the six nuclear power plants: Kozloduy 1-6. Their combined generating capacity totals 3 538 MW(e). The construction of an additional plant, Belene 1, was stoped in 1990, due to political and economical changes in the country.

Based on this information and the expected future retirement of some of these units the following projections are made.

Table 2. Installed Nuclear Generating Capacity [MW(e)]

1992	1993	1994	1995	1996	1997	2000	2005	2010
3 538	3 538	3 538	3 538	3 538	3 538	2 720	2 720	1 900

Table 3. Annual Reactor-Related Requirements [Tonnes U]

1992	1993	1994	1995	1996	1997	2000	2005	2010
844	844	844	844	844	844	649	649	453

NUCLEAR FUEL STRATEGY

The Beginning
Bulgarian nuclear power programme started in early 1960's, backed by scientific and technological development of the former Soviet Union. It's development in country is based on technical and economical support of former Soviet Union.

As in other communist countries ambitious programmes were started for radioisotope production for use in industry, medicine, agriculture, research. For these purpose in Bulgaria was created an Research 2 MW(e) Russian design IRT-2000 type reactor near Sofia belongs to Bulgarian Academy of Sciences (BAS). In fact this reactor is first step of the establishment and development of Bulgarian Nuclear Energetics.

The second step was a governmental decision in the late 1960, when it was taken to develop nuclear power plant for electricity generation at the Kozloduy site.

Current status

Nuclear Fuel from Research reactor IRT-2000

The reactor core consists of forty-eight 1 mm aluminium-coated assemblies where the oxide uranium fuel is placed with 10% enrichment of uranium 235. The reactor was commissioned in operation in September 1961 and operated for 24 600 hours altogether when in July 1989 it was shut down for the implementation of a modernisation and refurbishment programme on it.

The spent fuel stored up during that period of operation amounts to 73 assemblies out of wich 57 assemblies of 10% enrichment and 16 assemblies of 36% enrichment that is 184 kg heavy metal. At present this spent fuel is placed in a water-filled storage facility built within the reactor biological shield.

According to information received from the governing body of the BAS, the spent fuel from this reactor will be transported back to Russia within the scope of the Contract for transportation of Kozloduy NPP spent nuclear fuel back to Russia.

Nuclear Fuel from Kozloduy NPP

The Kozloduy NPP generated about 45% of the Bulgaria's electricity during 1998 [2]. It total production was just over 16 billion KWh (Appendix 3).

Six units with WWER Russian design reactors are in operation in Kozloduy (Appendix 4). According to their design the reactor core of WWER-440 units consists of 312 operative and 37 fuel elements of the control rods. Measures for reactor vessel protection against neutron embrittlement were taken and dummy assemblies replaced the operative assemblies along the core periphery of the first three units. That resulted in a reduction of the number of the reactor assemblies by 36. At present, 430 spent fuel assemblies on the average are received annually from the refueling of the four reactors which are stored according to their design in at-reactor pools for three years and then pursuant to an intergovernmental agreement are subject to the return to the country of manufacture, i.e. the former Soviet Union. Following the scheme, 3086 spent nuclear fuel assemblies from WWER-440 reactors on a zero value were sent back during the period 1979-1988.

Already in 1979, we were notified by the former Soviet Union of a change in the storage period of the spent fuel from 3 to 5 years and due to that reason an additional pool-type storage facility was built after a Soviet Union design. In 1989, the first assemblies were placed in that storage facility.

Unit No. 5 has been in operation since 1987 and Unit No. 6 - since 1991 equipped with WWER-1000 reactors whose core consists of 163 fuel assemblies of 3.3% enrichment of uranium 235, weight 430 kg heavy metal (HM) and each year one half of them is pulled out as spent fuel assemblies and stored on compact racks in the at-reactor basins. Refueling of reactors on a three year cycle has started since last year that will reduce by 30% the quantity of spent fuel for storage.

The Strategy

The attached table (Appendix 5) shows you the quantity of spent nuclear fuel stored to date on the plant site and the forecasted quantities till the end of the design life of the units in case of optimum use of fuel and conversion to fuel of prolonged service life and fuel burn-up.

In order to engage the Government of the country with this serious problem and meet the new requirement resulting from the conclusion of the IAEA's "Joint Convention on Safety Management of SNF and on Safety Management of Radioactive Waste", the new management of National Electricity Company (NEC) elaborated "Policy on Nuclear Fuel Cycle and RAW Management" which outlines the trends in the field till 2010 in prospect. This policy considers the prospects of development of the nuclear energy sector during the period when the first units of Kozloduy NPP will be decommissioned and replaced by new capacity.

The policy on spent nuclear fuel sets as primary objectives the requirements to use new, improved fuel of higher reliability and quality, prolonged service life and fuel burn-up that would provide a possibility of maximum reduction of costs for storing the spent nuclear fuel on the plant site. This will result in asking for new manufacturers of fresh nuclear fuel in Russia and in the world.

Adoption of such policy by the national Government would allow for accelerated completion of the actions taken with regard to the construction of a new dry spent nuclear fuel storage facility on the plant site and starting the project for construction of a new national storage for radioactive wastes from the spent nuclear fuel having been returned to Russia for reprocessing.

Action is being taken in three directions as follows:

- Reconstruction of the additional storage facility of basin type in order to receive a license from the National Regulatory Agency;
- Maximum packing of the at-reactor basins of the first four units;
- Return of limited quantities of spent nuclear fuel to Russia.

On the first direction, a project of European Bank for Research and Development (EBRD) through the Phare Programme is under way which is implemented by Bulgarian firms and its completion is planned for the end of the following year by getting a license from the Bulgarian Regulatory Agency.

A decision on whether to pack to the hightst possible degree the basins within this storage facility or to extend it with new adjacent basins is at hand.

On the second issue, a tender for a contractor who will pack the at-reactor basins of the first four units is in progress. The difficulties, we face, are only organisational since the plant management is not certain in the expedience of this work.

On the third direction, there is already a Framework Agreement for return of 480 assemblies from WWER-440 to Russia in place and at the end of September 1999 the first shipment of 8 canisters TK-6 containing 240 assemblies were transported and they were loaded on a barge following the existing transport route - Kozloduy NPP port, Reny port where the canisters were reloaded on railway wagons and transported across the territories of Moldova and Ukraine to the reprocessing plants in Russia.

The economic analyses of the various options of implementation of the new policy show that the costs are within the range of 200-800 million USD and in case of maximum use of the at-reactor basin capacity of the first four units and of the additional storage facility on site after their refurbishment and packing, costs will be the lowest. Return of the total quantity of SNF from the first four units (10034 assemblies) for reprocessing in Russia and construction of a new dry spent nuclear fuel storage facility for WWER-1000 will entail the greatest expense.

The last option will be implemented only if the other options cannot be realised within the set timeframe and temporary suspension of plant operation is enforced.

The policy does not consider an option of direct disposal of SNF as now it is regarded that there are not any national programme about that.

In conclusion one might say that it will be difficult to make up within the next year before the new century for the time lost in the last 10 years when problems with the SNF were not resolved. Such speedy actions will require significant amount of financial and material recources which the plant does not have now and we hope that by approving the Policy on Nuclear Fuel Cycle and Radioactive Waste Management developed by NEK the Government will do everything in its power to settle these difficult problems.

RADIOACTIVE WASTE MANAGEMENT

What does Radioactive Waste Management mean?
Radioactive Waste Management means all activities, administrative and operational that are involved in the handling, pre-treatment, treatment, conditioning, transportation, storage and disposal of waste from a nuclear facility [3].

The IAEA's Joint Convention on safety management of spent nuclear fuel and safety management of radioactive waste has defined more accurately that "radioactive waste management" means all activities, including decommissioning activities that relate to the handling, storage or disposal of radioactive waste, excluding off-site transportation [4].

The Law on the Use of Atomic Energy for Peaceful Purposes, issued in 1985, amended in 1995, determines the national policy on RWM. The Law provides general rules and legal frames for nuclear activities in the country.

The main responsible government organizations on Safety of Spent Nuclear Fuel Management and on the Safety of Radioactive Waste Management are shown in Appendix 6.

Safe Management of Radioactive Waste from NPP Kozloduy

Current Status

Liquid Waste

According to the Bulgarian regulations these kind of waste are to be classified as low level and medium level activity from 3.7x10 5 till 3.7x10 10 Bq/l. In fact they are produced after evaporation of radioactive waters received in NPP. The total amount of the liquid waste stored at Kozloduy NPP site exceeds 8000 cubic meters, including about 1600 cubic meters crystallised phase in the end of 1998. IAEA through its Technical Assistance Project BUL/9/016 "Radioactive Waste Treatment from NPP Kozloduy" helped us in 1990-1991 with project manager Mr. A. Tzarenko. Agency's expert Mr. D. Tankosic from USA with Bulgarian specialists developed a computer assessment programme for population's dose received by the liquid release from NPP. On its base the activity limit of liquid releases was corrected and the quantity of liquid radwastes is much smaller now.

There is not any information for total activity of the waste because it is not by project. They are kept in stainless steel storage tanks in auxiliary buildings №№ 1, 2 and 3. Each of them served two units of NPP. Installed storage capacity of all storage facilities is 8600 m 3.

Solid waste

The greater quantities of these kind of waste are low level and medium level radioactive waste. The surface gamma rate is from 1x10 -3 mSv/h till 10 mSv/h. Accumulated solid waste at NPP storage facilities in auxiliary buildings and in additionally built storage facilities is 7500 cubic meters. Their total activity is not defined up to now too.

The solid high level technological radioactive wastes with surface gamma rate above 10 mSv/h have small quantity, about 100 m 3. The storage facilities for them are built in reactor halls. They have enough capacity for these kind of waste for operational life time of each unit.

At present the storage facilities in auxiliary buildings 1 and 2 for liquid and solid waste are filled up. The extensions foreseen in their projects have not been constructed. To reserve the problem, after regulatory body instructions, Committee of Energy has procured facilities for final treatment of waste and a storage facility for storage of treated wastes. The construction of the facility is continuing now. It expects that the facilities will be in operation in 2000.

The Westinghouse contract schedule includes the following treatment installations:

- for cementation of liquid waste;
- for pressing of solid waste with supercompactor and
- for burning of radioactive contaminated oils.

Besides them there is a complex Canberra monitoring system and so on.

We accept the cementation treatment technology after Luwa evaporation system for liquid waste in Bulgaria.

The choice of the immobilization matrix depends on the physical and chemical nature of the wastes and the acceptance criteria for the disposal facility to which the waste will be considered [5].

As a packaging form it is accepted a reinforced concrete container with a capacity of 5 cubic meters. It has a license of the control body of the country as an IP-3 package, according to IAEA safety requirements.

Startegy

It recommends the following for waste management practices at the site:

- Redefining waste storage conditions to facilitate future waste treatment;
- Completing the systems for solidification of liquid waste and spent resins (based on a cementation technology) and the supercompactor for treating the dry active wastes;
- Developing process book for the whole waste treatment system covering all steps from collection to conditioning in BB-cube;
- Verifying the conformance of the process to quality assurance criteria and the conformance of the final waste form to waste acceptance criteria foe near surface repository;
- The establishment of clear responsibilities in the plant operational instructions with the aim of minimising waste arising at the plant, and, the motivation of the operators to minimise radioactive waste generation.

Safe Management of Radioactive Waste Received after Nuclear Applications. Repository

Current Status

The goal of radioactive waste management of these kind of waste is to ensure the safety operation and safety closed of their repository near Sofia namely Novi han and to project man and his environment from undue exposure to ionizing radiation from radioactive waste [6]. This is achieved by waste management practice which comply with the general radiation protection requirements as described in ICRP Publication 26 and IAEA Basic Safety Standards. This is postulated by the Principle 9: Safety of facilities of IAEATs fundamentals 329: Design, construction, operation and activity during decommissioning of a facility or closure of a repository should provide and maintain, where applicable an adequate level of protection to limit possible radiological impacts [7].

The Novi Han radioactive waste repository site has surface area about 60000 square meters. It is shallow land storage located in wooded area 35 km Southeast from Sofia city and 6 km far from Novi han village in Losen mountain. The storage was built on the Soviet type design TP-4891 of 1956. Novi Han was commissioned in October 1964. According to the Law on the Use of Atomic Energy for Peaceful Purposes these kind of waste are governmental property and this repository is its property also.

The assessment of the stored waste activity from 1967 till 1994 in the storage facility Novi Han shows that about 24800 Ci is from the waste from industry, 210 Ci from medicine and 8 Ci from research. It expects that for a period of 10 years it is possible to arise out of these kind of waste about 300000 Ci in the country.

On September 1994 the operation of Novi Han repository was stopped temporarily for it upgrading to comply with the current safety requirements to such type of facilities.

Strategy

- Upgrading the safety of the repository till the end of 2000;
- Receiving of a license from Bulgarian Safety Authority;
- Collection and treatment of radioactive waste from the country except for those from Kozloduy NPP;
- Long-term storage of treated RW with half life not exceeding 5 years and specific activity permitting its relief from monitoring in about 50 years;
- The related departments shall develop their own strategies of using ionizing radiation sources taking account of RW generation;
- Safety assessment of the Novi Han repository.

CONCLUSIONS

According to the Law in Bulgaria SNF is not any radioactive waste. In the near future, till 2010 year Bulgarian plans to return to Russia some quantities of SNF. It is possible through an agreement between Bulgarian and Russian government.

At the same time there is two approaches under development for wet storage and for dry storage of SNF for fifteen years at the NPP site. There is not any long term final disposal policy and plans in this field.

The responsibilities for the problem with SNF belongs to National Electricity Compani and Kozloduy NPP also at the moment.

In order to deal effectively SNF management and RW management in Bulgaria a new Waste Management Organization (WMO) should be established along the lines of other countries successfully undertaking disposal tasks.

According to the structure a new WMO particular attention is paid to the relationships between - and responsibilities of - the State, the Regulator, Waste Producers and the WMO. On the base of the IAEA guidance relating the subject we have to establish an appropriate RW Management structures and also to international analogues.

The model of the IAEA guidance on radwaste management infrastructure is sometimes referred to as the "classical triangle" principle. The model separates the three roles of the Regulator, the Waste Producer and the Waste Disposer. Each has separate responsibilities and must exhibit independence from the other. In principle, the nature of the new WMO should be along the following lines:

- It should be State owner, as under the law, the Government is ultimately responsible for radioactive waste;

- It should be non-profitable, but should aim to provide an optimal economic solution for disposal, whilst at the same time being consistent with environmental objectives.
- According to the Law on the Use of Atomic Energy for Peaceful Purposes issued in 1985, amended in 1995 there are created two funds for financing the radioactive waste management as follows:
- Safety management and safety disposal of radioactive waste;
- Decommissioning of nuclear facilities.

The money provides from all producers of radioactive wastes in the country.

REFERENCES

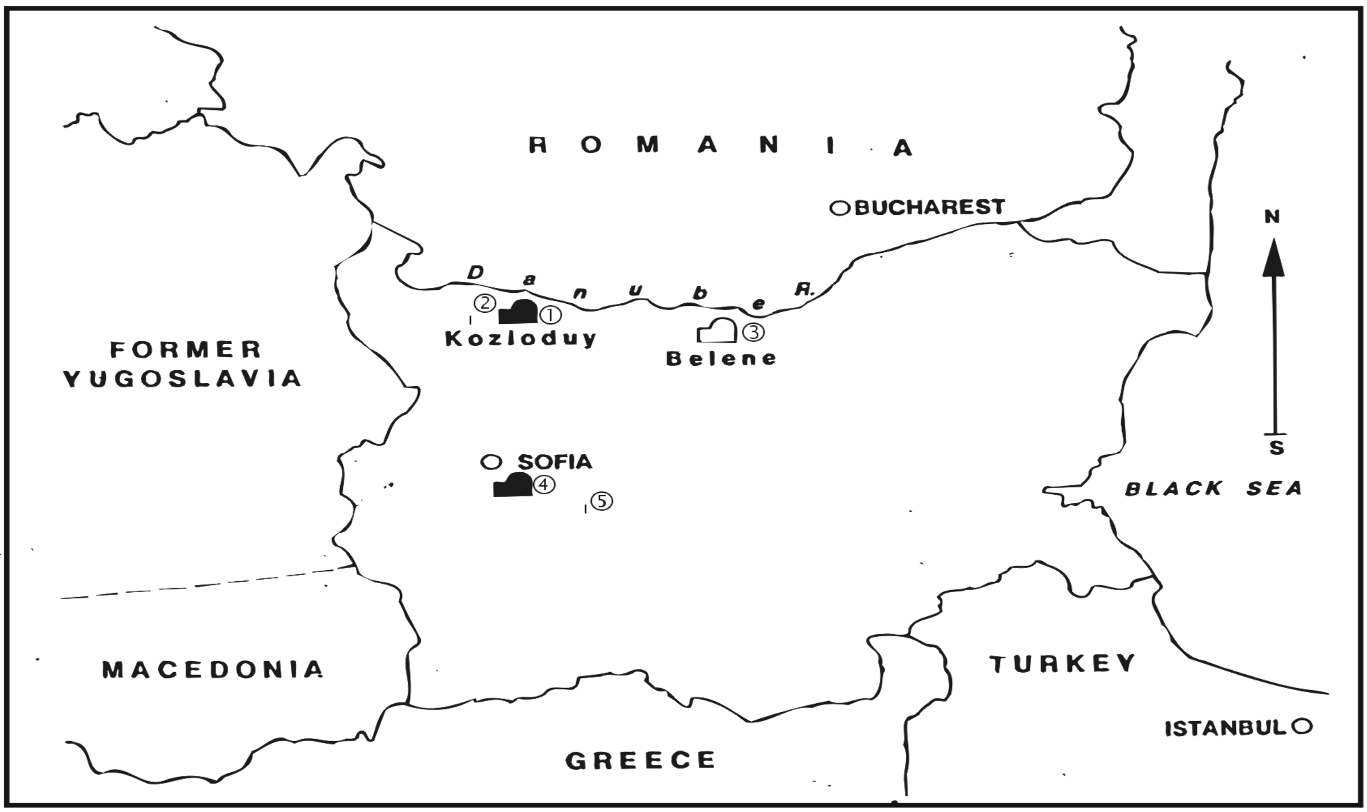
[1] Uranium Resources, Production and Demand, 1993, Joint Report by the Nuclear Energy Agency and International Atomic Energy Agency, Organization for Economic Co-operation and Development.
[2] The World's Nuclear News Agency, NucNet, October 20, 1998 (News № 383-85/98/B) № 383
[3] Radioactive Waste Management Glossary, IAEA, Vienna, 1993
[4] Joint Convention on Safe Management of SNF and Safe Management of Radioactive Waste, IAEA, Vienna, 1998
[5] Characterization of Radioactive Waste Forms and Packages, TSR №383, IAEA, Vienna, 1997
[6] Guidance for Radioactive Waste Management Legislation for Applications to Users of Radioindustry, IAEA-TECDOC-644, Vienna, 1992
[7] The Principles of Radioactive Waste Management, Safety Series № 111-F, IAEA, Vienna, 1995

Appendix 1

Location of Bulgaria in Europe

Appendix 2

Bulgaria's Borders



1. NPP Kozloduy
2. Spent Nuclear Fuel Wet Storage Facility
3. NPP Belene
4. Research Reactor
5. Surface Disposal Facility for RW after Nuclear Applications

Appendix 3

Kozloduy NPP Electricity Production (GWh) till 1998 (including)

	Gross	In house consumption, %	Net
Unit 1	57000	8.22	52314.6000
Unit 2	58292	8.14	53547.0312
Unit 3	47286	8.21	43403.8194
Unit 4	43971	7.91	40492.8939
Unit 5	42618	6.98	39643.2636
Unit 6	31712	6.38	29688.7744

Appendix 4

REACTOR STATUS CHECK LIST

Status	Reactor		Type	Capacity [MW(e)]		Construction Start	Grid Connection	Commercial Operation	Lifetime
	Code	Name		Net	Gross				
On grid	BG-1	Kozloduy-1	PWR 440/230	408	440	apr 70	24 jul 74	sep 74	30
	BG-2	Kozloduy-2	PWR 440/230	408	440	apr 70	1 oct 75	nov 75	30
	BG-3	Kozloduy-3	PWR 440/230	408	440	oct 73	dec 80	jan 81	30
	BG-4	Kozloduy-4	PWR 440/230	408	440	oct 73	1 may 82	jun 82	30
	BG-5	Kozloduy-5	PWR 1000/320	953	1000	jul 80	dec 86	jul 87	40
	BG-6	Kozloduy-6	PWR 1000/320	953	1000	jul 84	89	89	40

Appendix 5

SNF - number of Fuel Assemblies Taken Out of the Reactors by Years - Available and Projected Quantity by the end of the Design Life of the Units		
3-year fuel cycle		
Year	WWER-440	WWER-1000
1997	4300	619
1998	415	132
1999	430	109
2000	429	108
2001	429	109
2002	430	109
2003	429	108
2004	429	109
2005	638	109
2006	533	108
2007	221	109
2008	221	109
2009	220	108
2010	221	109
2011	221	109
2012	429	108
2013	349	109
2014		109
2015		108
2016		109
2017		109
2018		108
2019		218
2020		54
2021		54
2022		55
2023		163
Total	10 034	3 468
Tons HM	1200	1400

Appendix 6

GOVERNMENT ORGANIZATIONS ON SAFETY MANAGEMENT OF RADIOACTIVE WASTE

ORGANIZATION	RESPONSIBILITY ACTIVITIES
COMMITTEE ON THE USE OF ATOMIC ENERGY FOR PEACEFUL PURPOSES (CUAEPP)	• PROMOTION OF NUCLEAR POWER • REGULATORY BODY • FORMULATION OF THE SAFETY REQUIREMENTS • LICENSING • RADIATION SAFETY, CONTROL OF RADIOACTIVE MATERIALS, MONITORING • CONTROL BODY
GOVERNMENTAL AGENCY ON ENERGY AND ENERGY RESOURCES	• ALL ENERGY GENERATION AND DISTRIBUTION OVERSEES THE MANAGING BODIES OF NEC□FINANCE SOME RESEARCH AND DEVELOPMENT
NATIONAL ELECTRIC COMPANY (NEC)	• OWNS AND OPERATES ALL ELECTRICITY PLANTS
BULGARIAN ACADEMY OF SCIENCES (BAS)	• INSTITUTE FOR NUCLEAR RESEARCH AND NUCLEAR ENERGY IS RESPONSIBLE FOR THE OPERATION OF NOVI HAN REPOSITORY
ENERGOPROJECT	• INDEPENDENT STATE COMPANY ON DESIGN AND EVALUATION STUDIES
RISK ENGINEERING	• INDEPENDENT COMPANY ON DESIGN AND EVALUATION STUDIES
RESEARCH INSTITUTES	• RESEARCH PROGRAMMES IN THE FIELD OF RW MANAGEMENT